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THE GEYSERS OF MONTANA.

THE first detailed account we have of these wonders of geology was published by Mr. N. P. Langford, who was one of an exploring party under General Washburn, sent out in the summer of 1870. His article was published in "Scribner's Monthly," while the official report to Congress was written by Lieutenant Doane, U. S. A. From Professor F. V. Hayden's interesting and valuable report for 1871 we take the following still more extended account of these geysers, and are indebted to him for the use of the accompanying illustrations.

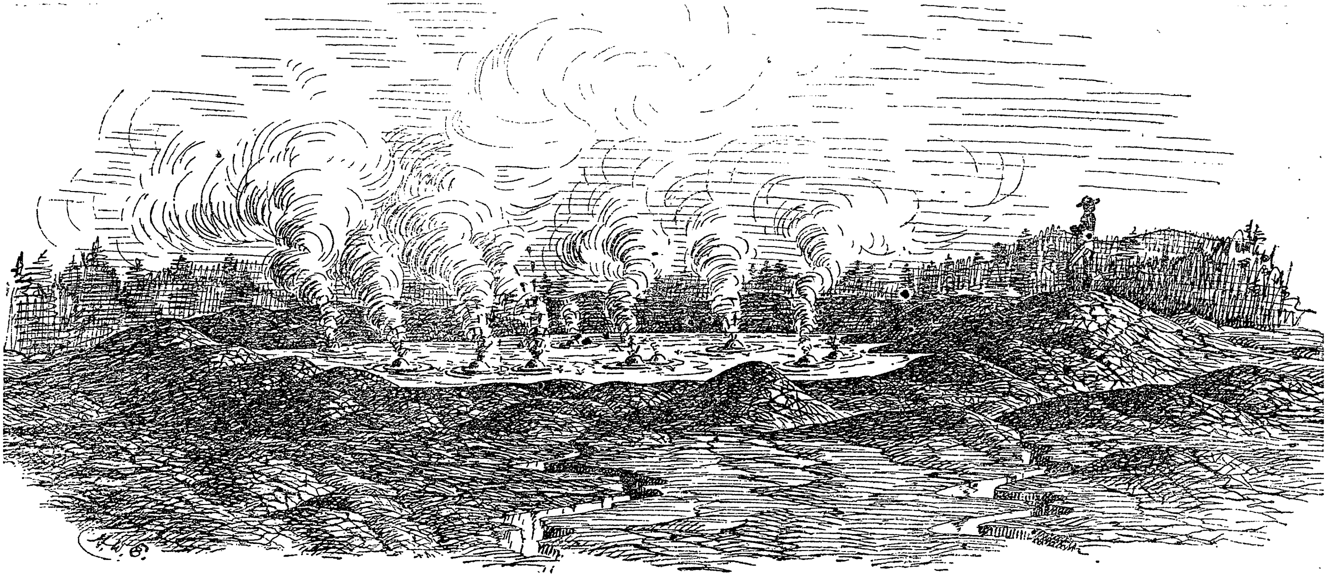
The geyser basin of Fire Hole river is near Yellowstone lake, the source of the Yellowstone river, of the wonders of which we give some account elsewhere in this number.

In the course of their wanderings in search of the Fire Hole basin the party under Prof. Hayden fortunately struck the sources of the East Fork of the Madison instead of those of the Fire Hole, and thus were enabled to see many fine springs which would otherwise have escaped attention, and there is no doubt, says Prof. Hayden, that subsequent explorations about the sources of the Yellowstone, Missouri and Snake rivers, will reveal many other groups of hot springs and geysers.

The entire valley of the East Fork, from its source to its junction with the Madison, extending over an area twenty-five miles long, and an average of half a mile in width, is covered with the silicious deposits of the hot springs, ancient and modern. The bed of the stream is lined with white silica, and the valley itself looks like an alkali flat. One group of thirty or forty springs is noticed, and the springs of the Lower Geyser basin are described and mapped. The main basin, the most beautiful of all in this last group, was ten by fifteen feet, the water 128°, marvellously transparent and of a most delicate blue; as the surface is stirred by the passing breeze, all the colors of the prism are shewn, literally a series of rainbows. He calls the most delicately colored springs Prismatic springs.

Entering the Fire Hole basin, the party visited one of the most remarkable mud-pots in the valley (Fig. 57). "The diameter

Fig. 57.

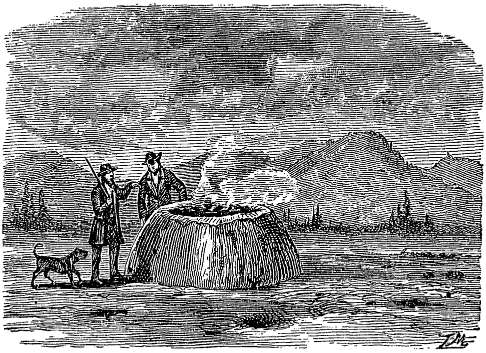


Mud Puff, Lower Fire-hole.

within the rim is forty by sixty feet, and forms a vast mortar bed of the finest material. The surface is covered with large puffs, and as each one bursts, the mud spurts upwards several feet with a suppressed thud. The mud is an impalpable, silicious clay, fine enough, it would seem, for the manufacture of the choicest ware. The colors are of every shade, from the purest white to a bright rich pink. The surface is covered with twenty or thirty of these puffs, which are bursting each second, tossing the mud in every direction on to the broad rounded rim. There are several other mud puffs in the vicinity, but they do not differ materially from the last, except in size."

We now come to the genuine geysers. Fig. 58 gives a view of one of the elevated craters called the Bee Hive; another much larger is styled the White Dome. "The broad mound is fifteen feet high, and upon this is a chimney about twenty feet in height. The steam issues steadily from the top like a high pressure engine."

Fig. 58.

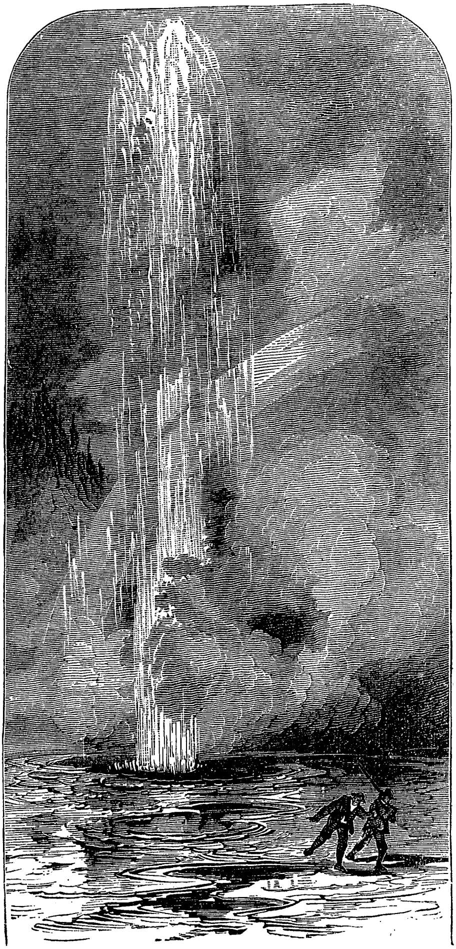


The Bee-hive.

We copy Prof. Hayden's description of this wonderful valley: —

"Early in the morning of August 30, the valley was literally filled with columns of steam, ascending from more than a thousand vents. I can compare the view to nothing but that of some manufacturing city like Pittsburgh, as seen from a high point, except that instead of the black coal smoke, there are here the white delicate clouds of steam. Small groups or solitary springs that are scattered everywhere in the woods, upon the mountain-sides, and which would otherwise have escaped observation, are detected by the columns of steam. It is evident that some of these groups of springs have changed their base of operations within a comparatively recent period; for about midway on the east side of the lower basin there is a large area covered with a thick, apparently modern, deposit of the silica, as white as snow, while standing quite thickly all around are the dead pines, which appear to have been destroyed by the excessive overflow of the water and the increased deposition. These dry trees have a most desolate look; many of them have fallen down and are incrusted with the silica, while portions that have fallen into the boiling springs have been reduced to a pulp. This seems to be one of the conditions of silicification, for when these pulpy masses of wood are permitted to dry by the cessation of the springs, the most perfect specimens of petrified wood are the result. In one instance a green pine-tree had fallen so as to immerse its thick top in a large hot basin, and leaves, twigs and cones had become completely incrusted with the white silica, and a portion had entered into the cellular structure, so that when removed from the water, and dried in the sun, very fair specimens were obtained."

Fig. 59.

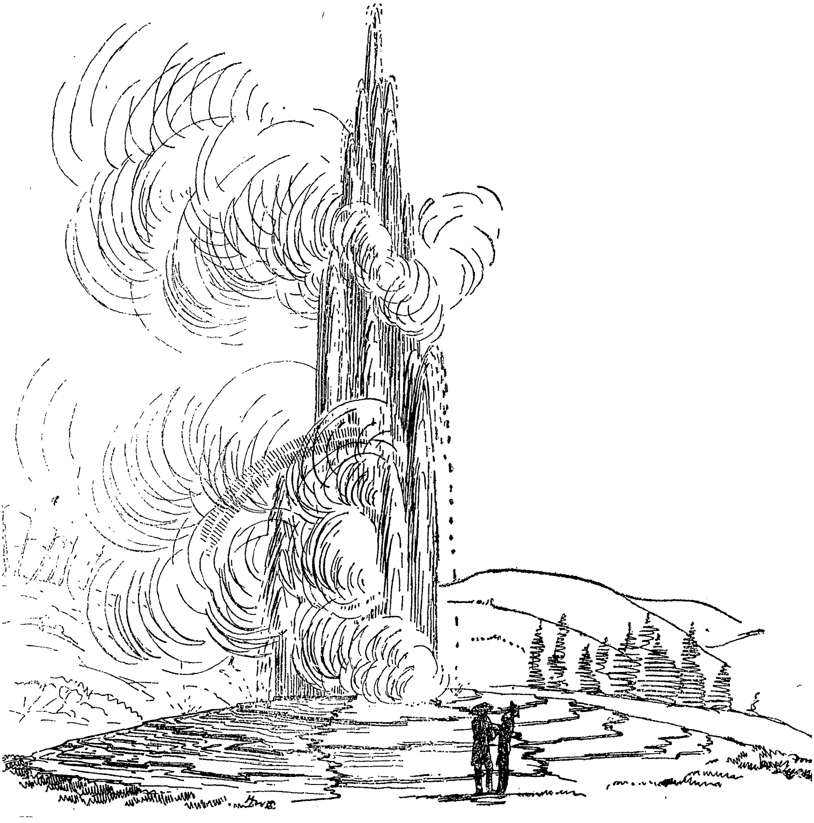


Grand Geyser.

The Upper Geyser basin contains the most remarkable geysers, of which the first one is the Grand Geyser (Fig. 59). Says Hayden:—

"Soon after reaching camp a tremendous rumbling was heard, shaking the ground in every direction, and soon a column of steam burst forth from a crater near the edge of the east side of the river. Following the steam, arose by a succession of impulses, a column of water, apparently 6 feet in diameter, to the height of 200 feet, while the steam ascended a thousand feet or more. It would be difficult to describe the intense excitement which attended such a display. It is probable that if we could have remained in the valley several days, and become accustomed to all the preliminary warnings, the excitement would have ceased, and we could have admired calmly the marvellous ease and beauty with which this column of hot water was held up to that great height for the space of twenty minutes. After the display is over the water settles down in the basin several inches, and the temperature slowly falls to 150°. We called this the Grand Geyser, for its power seemed

Fig. 60.



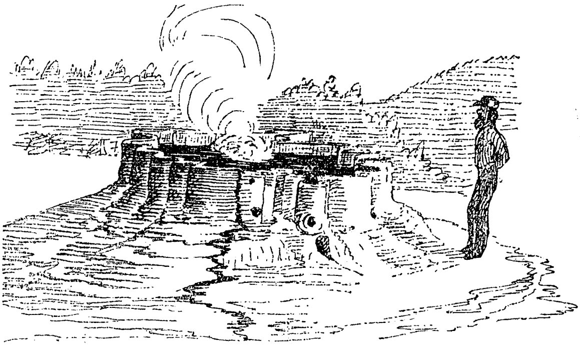
Grand Geyser, Upper Geyser Basin, Fire-hole River.

greater than any other of which we obtained any knowledge in the valley. (Fig. 59.) There are two orifices in one basin; one of them seems to have no raised rim, and is a very modest-looking spring in a state of quiescence, and no one would for a moment suspect the power that was temporarily slumbering below. The orifice is oblong, 2½ by 4 feet, while for the space of 10 feet in every direction around it are rounded masses of silica, from a few inches to 3 feet in diameter, looking like spongiform corals. Nothing could exceed the crystal clearness of the water."

Fig. 60 gives a view of another eruption of the same geyser.

As an example of exhausted geysers may be cited the Punch Bowl (Fig. 61), which is a low crater or chimney in which the water boils two or three feet high only. A large example of a rugged crater is the Giant (Fig. 62), which says Mr. Langford, in "Scribner's Monthly" "has a rugged crater, ten feet in diameter on the outside, with an irregular orifice five or six feet in diameter. It discharges a vast body of water, and the only time we saw it in eruption the flow of water in a column five feet in diameter, and one hundred and forty feet in vertical height, continued uninterruptedly for nearly three hours. The crater resembles a miniature model of the Coliseum."

Fig. 61.

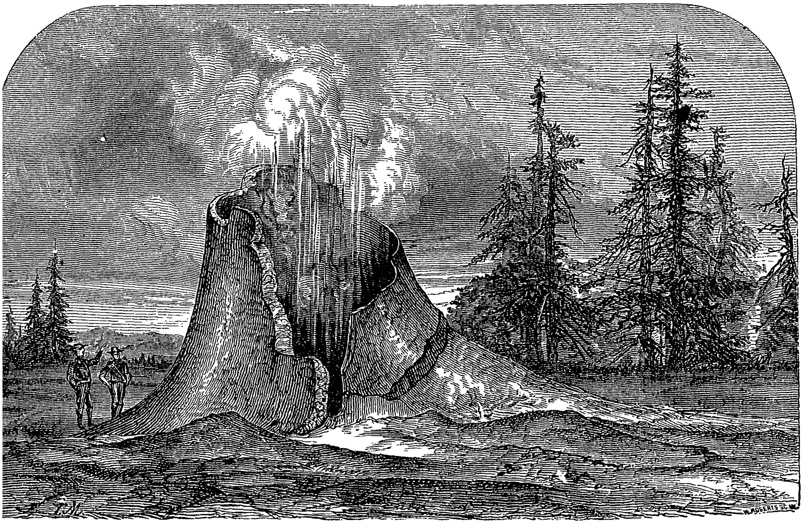


Punch Bowl.

The "Giantess," however, honored the party with a grand eruption, an account of which we give in Prof. Hayden's own words: —

" Our search for new wonders leading us across the Fire-Hole river, we ascended a gentle incrusted slope, and came suddenly upon a large oval aperture with scalloped edges, the diameters of which were 18 and 25 feet, the sides corrugated and covered with a grayish-white silicious deposit, which was distinctly visible at the depth of 100 feet below the surface. No water could be discovered, but we could distinctly hear it gurgling and boiling at a great distance below. Suddenly it began to rise, boiling and spluttering, and sending out huge masses of steam, causing a general stampede of our company, driving us some distance from our point of observation. When within about 40 feet of the surface, it became stationary, and we returned to look down upon it. It was foaming and surging at a terrible rate, occasionally emitting small jets of hot water nearly to the mouth of the orifice. All at once it seemed seized with a fearful spasm, and rose with incredible rapidity, hardly affording us time to flee to a safe distance, when it burst from the orifice with terrific momentum, rising in a column the full size of this immense aperture to the height of 60 feet; and through and out of the apex of this vast aqueous mass, five or six lesser jets or round columns of water, varying in size from 6 to 15 inches in diameter, were projected to the marvellous height of 250 feet. These lesser jets, so much higher than the main column, and shooting through it, doubtless proceed from auxiliary pipes leading into the principal orifice near the bottom, where the explosive force is greater. If the theory that water by constant boiling becomes explosive when freed from air be true, this theory rationally accounts for all irregularities in the eruptions of the geysers.

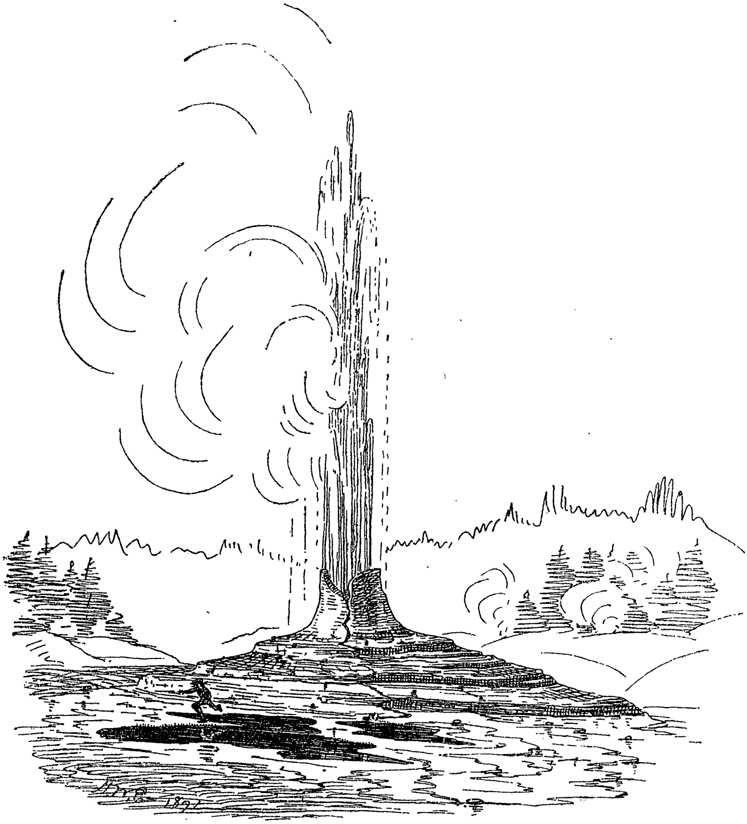
Fig. 62.



The Giant.

This grand eruption continued for twenty minutes, and was the most magnificent sight we ever witnessed. We were standing on the side of the geysers nearest the sun, the gleams of which filled the sparkling column of water and spray with myriads of rainbows, whose arches were constantly changing — dipping and fluttering hither and thither, and disappearing only to be succeeded by others, again and again, amid the aqueous column, while the minute globules into which the spent jets were diffused when falling sparkled like a shower of diamonds, and around every shadow which the denser clouds of vapor, interrupting the sun's rays, cast upon the column, could be seen a luminous circle radiant with all the colors of the prism, and resembling the halo of glory represented in paintings as encircling the head of Divinity. All that we had previously witnessed seemed tame in comparison with the perfect grandeur and beauty of this display. Two of these wonder-

Fig. 63.



Old Faithful, Upper Geyser Basin, Fire-hole River.

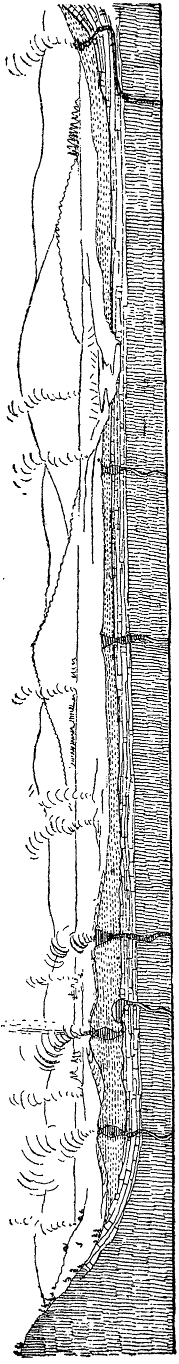


Fig. 64.

Ideal Section, Upper Geyser Basin, Fire-hole River.

ful eruptions occurred during the twenty-two hours we remained in the valley. This geyser we named "The Giantess."

Another fine geyser is "Old Faithful" (Fig. 63), as it was christened by Messrs. Langford and Doane. It shoots up a column of water about six feet in diameter to the height of 100 to 150 feet, "and by a succession of impulses seemed to hold it up steadily for the space of fifteen minutes, the great mass of water falling directly back into the basin, and flowing over the edges and down the sides in large streams. When the action ceases, the water recedes beyond sight, and nothing is heard but the occasional escape of steam until another exhibition occurs."

Fig. 64 is an ideal section of a portion of the Upper Geyser Valley sketched by Mr. Elliott for the purpose of conveying a "clearer conception of the way in which we may suppose the waters of many of the springs reach the surface. The lower portion of the section is basalt, then lake or local drift deposits, and thirdly the crust of silica, which forms a floor of greater or less thickness for the entire valley."

It is evident that the geysers of Iceland are tame in comparison with those of Montana, while the latter are similar to those of New Zealand. Concerning the origin of geysers, Hayden quotes as follows from Hochstetter's "New Zealand:"

> "Both kinds of springs owe their origin to the water permeating the surface and sinking through fissures into the bowels of the earth, where it becomes heated by the still existing volcanic fires. High-pressure steam is thus generated, which, accompanied by volcanic gases, such as muriatic acid, sulphurous acid, sulphuretted hydrogen, and carbonic acid, rises

again toward the colder surface, and is there condensed into hot water. The over-heated steam, however, and the gases decompose the rock beneath, dissolve certain ingredients, and deposit them on the surface. According to Bunsen's ingenious observations, a chronological succession takes place in the coöperation of the gases. The sulphurous acid acts first. It must be generated there where rising sulphur vapor comes into contact with glowing masses of rock. Wherever vapors of sulphurous acid are constantly formed, there acid springs, or solfataras, arise. Incrustations of alum are very common in such places, arising from the action of sulphuric acid on the alumina and alkali of the lavas; another product of the decomposition of the lavas is gypsum, or sulphate of lime, the residuum being a more or less ferruginous fumarole clay, the material of the mudpools. To the sulphurous acid comes sulphuretted hydrogen, produced by the action of steam upon sulphides, and by the mutual decomposition of the sulphuretted hydrogen and sulphurous acid, sulphur is formed, which in all solfataras forms the characteristic precipitate, while the decomposition of silicious incrustations is either entirely wanting or quite inconsiderable, and a smell of sulphuretted hydrogen is but rarely noticed. These acid springs have no periodical outbursts of water.

In course of time, however, the source of sulphurous acid becomes exhausted, and sulphuretted hydrogen alone remains active. The acid reaction of the soil disappears, yielding to an alkaline reaction by the formation of sulphides. At the same time the action of carbonic acid begins upon the rocks, and the alkaline bicarbonates thus produced dissolve the silica, which, on the evaporation of the water, deposits in the form of opal, or quartz, or silicious earth, and thus the shell of the springs is formed, upon the structure of which the periodicity of the outbursts depends. Professor Bunsen, rejecting the antiquated theory of Makenzie, based upon the existence of subterraneous chambers, from which the water, from time to time, is pressed up through the vapors accumulating on its surface, according to the principle of the Hern fountain, has proved in the case of the great geyser that the periodical eruptions or explosions essentially depend upon the existence of a frame of silicious deposits, with a deep, flue-shaped tube, and upon the sudden development of larger masses of steam from the overheated water in the lower portions of the tube. The deposition of silica in quantities sufficient for the formation of this spring apparatus in the course of years takes place only in the alkaline springs. Their water is either entirely neutral or has a slightly alkaline reaction. Silica, chloride of sodium, carbonates, and sulphates are the chief ingredients dissolved in it. In the place of sulphurous acid the odor of sulphuretted hydrogen is sometimes observed in these springs.

The rocks, from which the silicious hot-springs of New Zealand derive their silica, are rhyolites, and rhyolithic tufas, containing seventy and more per cent. of silica; while we know that in

Iceland palagonite, and palagonitic tufas, with fifty per cent. of silica, are considered as the material acted upon and lixiviated by the hot water. By the gradual cooling of the volcanic rocks under the surface of the earth in the course of centuries the hot springs also will gradually disappear; for they too are but a transient phenomenon in the eternal change of everything created." — (Hochstetter's "New Zealand," English translation, p. 432.)

Bischof in his "Researches into the internal heat of the globe," thus discourses on the origin of the Geysers of Iceland: —

"No doubt can be entertained respecting the nature of the agent by which the waters of the geyser, the Strokr, and other less considerable springs, are thrown to such an immense height. It is, as in volcanoes, a gaseous body, principally aqueous vapor. We may, therefore, very fairly agree with Krug Von Nidda, and consider volcanoes in the same light as intermittent springs, with this difference only, that instead of water, they throw out melted matters.

"He takes it for granted that these hot springs derive their temperature from aqueous vapors rising from below. When these vapors are able to rise freely in a continual column, the water at the different depths must have a constant temperature, equal to that at which water would boil under the pressure existing at the respective depths; hence the constant ebullition of the permanent springs and their boiling heat. If, on the other hand, the vapors be prevented by the complicated windings of its channels from rising to the surface; if, for example, they be arrested in caverns, the temperature in the upper layers of water must necessarily become reduced, because a large quantity of it is lost by evaporation at the surface, which cannot be replaced from below. And any circulation of the layers of water at different temperatures, by reason of their unequal specific gravities, seems to be very much interrupted by the narrowness and sinuosity of the passage. The intermitting springs of Iceland are probably caused by the existence of caverns, in which the vapor is retained by the pressure of the column of water in the channel which leads to the surface. Here this vapor collects, and presses the water in the cavern downward until its elastic force becomes sufficiently great to effect a passage through the column of water which confines it. The violent escape of the vapor causes the thunder-like subterranean sound and the trembling of the earth which precedes each eruption. The vapors do not appear at the surface till they have heated the water to their own temperature. When so much vapor has escaped that the expansive force of that which remains has become less than the pressure of the confining column of water, tranquillity is restored, and this lasts until such a quantity of vapor is again collected as to produce a fresh eruption. The spouting of the spring is therefore repeated at intervals, depending upon the capacity of the cavern, the height of the column of water, and the heat generated below."

With this work and the admirable series of photographs by Mr. Jackson (both in sheets * and stereoscopic form, published by Prof. Hayden) of some of the finest views in the National Yellowstone Park and Colorado Territory, the reader can obtain a very clear idea of the Geyser region, of the springs in course of eruption, and of the falls and basin of the Yellowstone. We see by the papers that it is proposed to open roads into the National Park, and erect hotels at the Geysers for the convenience of the public.

ON SOME OF PROF. MARSH'S CRITICISMS.

BY E. D. COPE.

I.

I have already (in "The short-footed Ungulata of the Eocene of Wyoming;" Naturalists' Agency, Salem, Mass.) shown, by figures and descriptions, the absence of foundation for Professor Marsh's recent animadversions, and though these latter present internal evidence of idiosyncracy which almost disarms reply, yet as some of the readers of this journal may not see the above essay, I make a few specific contradictions of some of his statements which may be regarded as serious.

In an article "On the Gigantic Fossil Mammals of the Order Dinocerata," he writes as follows:

"(1) What Prof. Cope has called incisors are canines, etc." I had determined and stated them to be canines, in the American Naturalist, previous to the appearance of this criticism.

"(2) The stout horns he described are not on the frontals but on the maxillaries." I was the first to determine these bones to be nasals, and find that in *Eobasileus* they compose the inner face of the horns to the apex, while the maxillaries form the outer face. †

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* Sun Pictures of Rocky Mountain Scenery. By F. V. Hayden. The Rocky Mountain Album. By F. V. Hayden and A. H. Jackson, Photographer.

† (See my paper, p. 18). Professor Marsh has since contradicted the former statement flatly.